CERES AND THE S'COOL PROJECT

Lin H. Chambers, David F. Young, Bruce R. Barkstrom, and Bruce A. Wielicki, Radiation Sciences Branch, Atmospheric Sciences Division, MS 420, NASA Langley Research Center, Hampton, VA 23681-0001 USA. L.H.Chambers@larc.nasa.gov

Abstract. The first Clouds and the Earth's Radiant Energy System (CERES) instrument will be launched on the Tropical Rainfall Measuring Mission (TRMM) spacecraft from a Japanese launch site in November 1997. This instrument is a follow-on to the Earth Radiation Budget Experiment (ERBE) begun in the 1980's. The instrument will measure the radiation budget - incoming and outgoing radiant energy - of the Earth. It will establish a baseline and look for climatic trends. The major feature of interest is clouds, which play a very strong role in regulating our climate. CERES will identify clear and cloudy regions and determine cloud physical and microphysical properties using imager data from a companion instrument. Validation efforts for the remote sensing algorithms will be intensive. As one component of the validation, the S'COOL (Students' Cloud Observations On-Line) project will involve school children from around the globe in making ground truth measurements at the time of a CERES overpass. Their observations will be collected at the NASA Langley Distributed Active Archive Center (DAAC) and made available over the Internet for educational purposes as well as for use by the CERES Science Team in validation efforts. Pilot testing of the S'COOL project began in January 1997 with two local schools in Southeastern Virginia and one remote site in Montana. This experience is helping guide the development of the S'COOL project. National testing is planned for April 1997, international testing for July 1997, and global testing for October 1997. In 1998, when the CERES instrument is operational, a global observer network should be in place providing useful information to the scientists and learning opportunities to the students.

Acronyms and Symbols

ADM	Angular Distribution Model
AVHRR	Advanced Very High Resolution Radiometer
CERES	Clouds and the Earth's Radiant Energy System
DAAC	Distributed Active Archive Center
EOS	Earth Observing System
ERBE	Earth Radiation Budget Experiment
F	Radiative flux, W/m^2
I	Measured radiance, W/m^2-sr
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
R	Anisotropic factor
RAPS	Rotating Azimuth Plane Scanner
S'COOL	Students' Cloud Observations On-Line
TOA	Top-of-Atmosphere
TRMM	Tropical Rainfall Measuring Mission

Background

The Earth's climate is determined in large part by its energy, or radiation, budget. A schematic summarizing the radiation processes in the Earth's current climate is shown in Figure 1. A large part of the reflected (shortwave) component of the outgoing radiation is due to clouds, while more than a third of the emitted (longwave) component comes from clouds. Thus an understanding of clouds and how they interact with the rest of the climate system is necessary before accurate predictions of climate change can be made. Better knowledge of cloud processes may also lead to improved long-range weather forecasting.

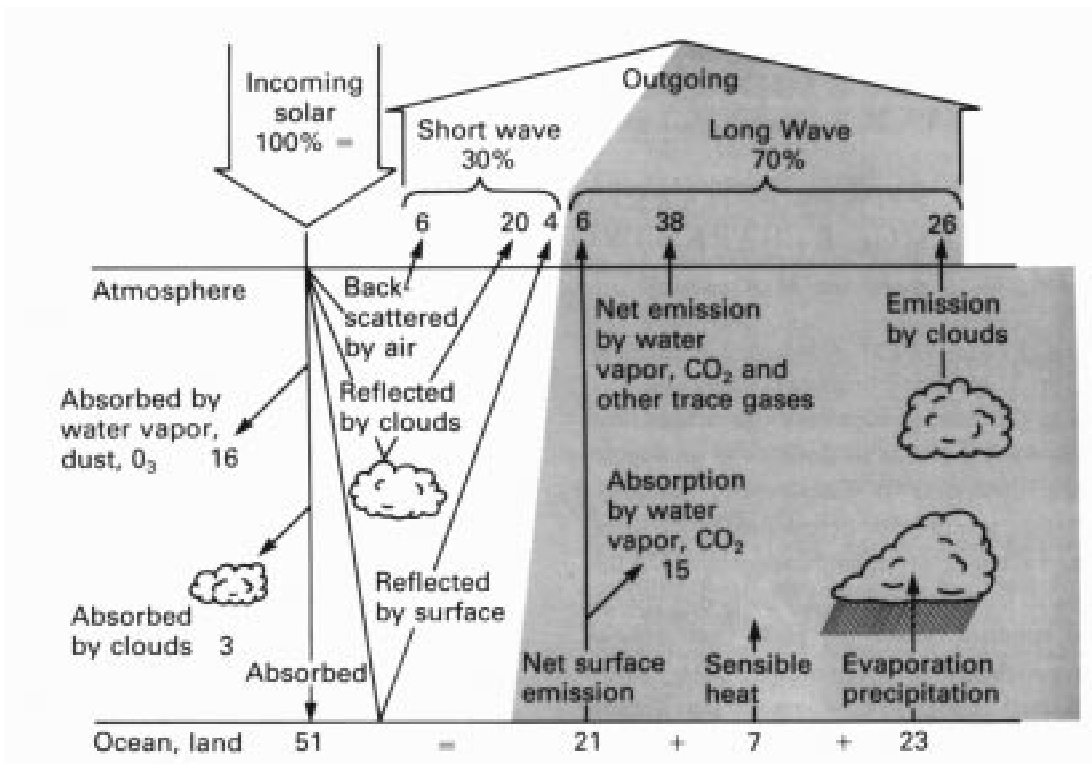

Figure 1: Earth Radiation Budget Processes (from Ref. 1)

The Earth's radiation budget has been monitored on a global basis using spaceborne instruments since the mid 1970's (Nimbus-6 and 7). The ERBE project (Ref. 2) operated instruments on a number of satellite platforms starting in 1984, some of which continue to function today. Recent measurements by the SCAnner for RAdiation Budget (SCARAB; Refs. 3, 4) augmented this dataset for about a year. These instruments were designed principally to measure the energy fluxes at the top of the Earth's atmosphere (TOA). ERBE classified the radiative behavior of the Earth-atmosphere system using 12 scene types, such as "clear over ocean", and "mostly cloudy over land or desert". For each scene type it used an angular distribution model (ADM) built from Nimbus-7 data to convert from satellite-measured radiance to hemispherical flux: $F=\pi I/R$, where R is the anisotropic factor from the ADM. ERBE's field of view was small enough to allow it to see clear areas between clouds at least part of the time. A comparison of clear and cloudy fluxes could then be used to measure the net radiative forcing of clouds, i.e., the net effect of clouds on the Earth's energy budget. ERBE found that on a global basis, in the current climate, clouds act to cool the Earth during all seasons (Ref. 5). A closer look at the data, in combination with global data on cloud distribution, shows that different clouds have different effects (Table 1, adapted from Ref. 6). Furthermore, the tropics are found to be in near radiative balance, while cooling is greatest over mid-latitude oceans. These findings have led to increased interest in clouds within the climate community, such that this issue is one of the highest priorities in global change research.

Table 1: Climatological Effects of Clouds

Cloud Class	Effect	Magnitude	Area Coverage
High thin	Warm	+23	10%
High thick	Cool	-80	9%
Mid thin	Warm	+10	11%
Mid thick	Cool	-103	7%
Low	Cool	-62	26%

The ERBE data are available to researchers and interested individuals around the world from the Langley DAAC (Ref. 7).

CERES

The CERES experiment (Ref. 8) is being designed as a follow-on to the aging ERBE instruments. CERES instruments will operate on a number of platforms as part of the NASA's Mission to Planet Earth over a period of at least 15 years. The first will be launched from Tanegashima on the Japanese TRMM spacecraft in November 1997. CERES will make measurements with better spatial resolution than ERBE, and will fly on satellites carrying imagers that will assist in identifying and classifying clouds within the field of view. Cloud parameters to be obtained include the cloud fraction, cloud height, and cloud optical depth, as well as the particle phase and size. Fundamentally, CERES will provide an extension of the ERBE record of TOA radiative flux data to allow detection of any climate change signal. The high resolution imager instruments will enable improved determination of the radiative scene type -- up to 200 scene types and associated ADMs are planned -- and therefore produce improved measurements of cloud radiative forcing. CERES will also provide an initial determination of radiative fluxes within the atmosphere and at the surface, using sounding and cloud property information from companion instruments. A factor of 2 to 3 reduction in TOA radiative flux error is anticipated compared to ERBE.

A CERES instrument consists of a three-channel scanning broadband radiometer. It has a nadir field of view of about 20 km. The three channels measure the total (0.2 - 100 μm), shortwave

(0.2 - 5 μm) and longwave window (8 - 12 μm) radiation; the latter to assist in obtaining within-atmosphere and surface fluxes. The instrument scans across the earth and back every 6.6 seconds, with an internal calibration in the middle of each scan. Solar calibrations are performed every two weeks to monitor the stability of the instrument sensor. The scanner can operate either in cross-track mode (scanning left and right as it moves along the orbit) or in rotating azimuth plane scanner (RAPS) mode. RAPS mode increases the sampling in angular space (solar zenith, solar azimuth, view zenith, view azimuth) in order to more rapidly obtain measurements to build ADMs. On the TRMM platform, which has a precessing orbit, CERES will provide data between latitudes of 35 S to 35 N. Additional CERES instruments will be launched on the EOS-AM platform in June, 1998 (sun-synchronous polar orbit with equator crossing at 1030 local time) and the EOS-PM platform in 2000 (1330 sun-synchronous polar orbit). These instruments will provide global coverage.

Validation. Validation of TOA fluxes is only possible by comparison to other space-based measurements. Few, if any, will be available in the CERES timeframe. As in ERBE, therefore, consistency checks will be used to validate the TOA results. Validation of the within atmosphere and surface fluxes will rely on data from intensive field campaigns and on-going validation studies such as the Department of Energy's Atmospheric Radiation Measurement program and the Baseline Surface Radiation Network. Validation of cloud property retrievals will also rely on these sites. Areas of active research include detection of clouds in polar areas and over snow, ice, or bright surfaces in general; detection of broken low level clouds, multilayer clouds, and subvisible cirrus; and discrimination of clouds from smoke or dust. Some data for validation of cloud property retrievals will be provided by an educational outreach project, described in the following section. Based on the ERBE experience, CERES validation efforts will likely focus first on the climate months of January and April 1998.

The S'COOL Project

History. The S'COOL project was initiated in December 1996 following an informal conversation with a middle school (6th grade) teacher from Gloucester, Virginia, USA. She was seeking a simple, safe, and cheap experiment that her students could do, the results of which could be sent to NASA. She viewed the connection to NASA as a way to both motivate her students, and to connect them to the world around them. If the results were of use to NASA, so much the better. Using school students as cloud observers for CERES fits perfectly into the teacher's requirements and provides information to researchers which would not otherwise be available. The short lifetime of clouds (5-10 minutes on average) means coincident observations are very important for comparison to satellite data.

Concept. School students around the world will go outside at the time a CERES instrument in orbit is viewing their location and make an observation of the clouds in the sky (cloud type, fraction, height, and an estimate of opacity), some related meteorological data (temperature, pressure, relative humidity), and the ground cover (snow, foliage, etc.). They will report their observations to a central archive at the Langley DAAC, keeper of the CERES data (Ref. 7). Once the satellite observations are processed, the students will be able to obtain these measurements via the Internet to compare with what they reported. The students' observations will be kept in a database which will be available for use as validation data by the CERES Science Team and other researchers, as well as for educational use by school teachers.

Development. The S'COOL project is being developed in an incremental fashion (Table 2), with test phases during January, April, July, and October 1997. During the test phases existing operational satellites are being used as a stand-in for CERES. The January pilot test was a feasibility test, using the Advanced Very High Resolution Radiometer (AVHRR) instrument on the NOAA-14 spacecraft, to determine how students reacted to the project and whether it was worth pursuing. It was carried out after minimal materials were developed, with personal visits to the classroom by several NASA researchers to instruct the students about the project. The response exceeded all expectations, so development has proceeded apace. Interim tests were carried out with a 6th grade class in Big Timber, Montana, USA to exercise the e-mail interface, and with a 4th grade class in Poquoson, Virginia, USA to test the Internet interface. All tests resulted in identification of issues needing work, and also generated additional ideas for the S'COOL project. In particular, the teacher of the Poquoson class reported that her students learned from the project "across the curriculum", from math and science to language arts and vocabulary.

Table 2: Development Schedule for S'COOL Project

Phase	Date	Scope	Test	Goal
1	January 1997	Local	Concept	Go/Nogo
2	April 1997	National	Interface	Automation
3	July 1997	International	Interface	More automation
4	October 1997	Global	Capacity	Max. automation
5	January 1998	Global	TRMM spacecraft	Correct orbit
Operational	April 1998 ->	Global	Periodic or on-going activation	Validation data

A national test in the USA at the end of April 1997 is planned to test automated operation of the project without school visits by NASA researchers. Invitations were sent to 30 individuals in different states in an attempt to obtain broad geographic coverage and thus increase the range of cloud and surface types sampled. Ten schools around the country have asked to participate (Figure 2). The teachers involved will implement the project using the information on the S'COOL website (Ref. 9) and a one page instruction sheet that was mailed to them. They will be asked to provide feedback on their experience with the project and on the materials developed to date, as well as to provide comments on other materials they believe still need to be developed. Schools east of the Mississippi River will make observations coinciding with overpasses of the AVHRR instrument on NOAA-14, while those in the west will coordinate with GOES satellite observations at 1800 GMT. Limited feedback will be provided, with comparisons to one day of satellite measurements for each participating site.

Figure 2: S'COOL Participant Locations for Phase 2, April 1997

Given school schedules, the July 1997 test will be an international test focussing on the southern hemisphere. This test will continue to expand geographic coverage (initial contacts have been identified in Argentina, Australia, Brazil, Chile, Korea, the Philippines, and South Africa) and explore issues such as language and technology barriers for international participants. Automated access to the AVHRR overpass times will be essential for this phase of the development. A test in October 1997 is planned to be of the operational S'COOL system, with participation from around the globe and automation of all elements of the interface. By January 1998, when the CERES instrument on TRMM is expected to begin providing regular measurements, a global network of student observers should be in place. Observations may then be made as they fit the schedule of each participating class, or on a focussed basis for validation periods.

Design. The S'COOL project is being designed to exploit the Internet and related technology to a maximum extent in order to minimize the manpower required to run the project. A website has been created (Ref. 9) and is intended to be the primary interface with participants. Any print material that is found to be necessary will be developed from the information on the website. In particular, registration and report forms are available on-line. An orbital interface, to allow participants to determine CERES overpass times for their location via a simple Internet form, is in the planning stages. On-line access to the database of global S'COOL observations is also being designed. This will allow participants to retrieve all S'COOL observations for a given time period and study the variation of clouds in different regions of the Earth. A companion database of satellite results is being contemplated as well. Development of this part of the project will depend on the availability of validated CERES products for release.

Summary

The climate of our Earth is controlled by a complex system of interacting parts. Monitoring the system over the long term and on a global basis is necessary to understanding our planet and the changes humans may be inducing. Global monitoring of the radiation budget began with satellite instruments launched in the mid-1970's and will continue this year with the launch of the first CERES instrument in November. CERES represents a large improvement in our ability to monitor the Earth radiation budget and the role of clouds on a global basis, in order to understand how they interact with the climate system. As part of the validation efforts for CERES, the S'COOL project is being developed. S'COOL will involve school children around the globe as cloud observers. Participating classes will provide cloud observations and related measurements at the time of a CERES overpass and transmit them for archive in the Langley DAAC. These observations will be available to the CERES Science Team for use in validating and improving cloud retrieval algorithms; and to educators worldwide for educational purposes. Anyone interested in further information on S'COOL, or in becoming a participant, is invited to contact the first author.

Acknowledgments

The S'COOL project is a joint effort of NASA Langley's Atmospheric Sciences Division, the Langley DAAC (principally Anne Racel and Walt Baskin), and NASA Langley's Office of Education (principally Jane George).

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